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THE AXIAL LOADING CORROSION FATIGUE PROPERTIES OF 25 MM THICK H--ETC(U)
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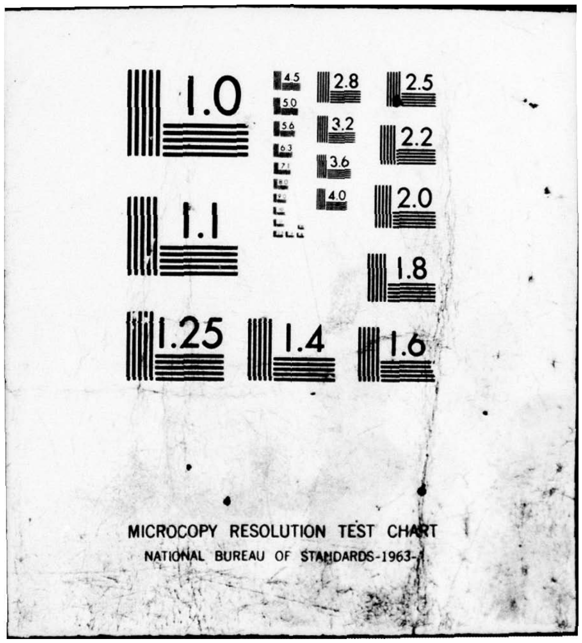
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6 THE AXIAL LOADING CORROSION FATIGUE PROPERTIES OF 25mm THICK HIGH AND LOW STRENGTH X166 PLATE (DTD 5120 AND DTD 5130)

by

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SUMMARY

Axial loading fatigue tests have been made at R = 0.1 in laboratory air and in a 3½% NaCl fog using holed transverse sheet type test pieces (K_T = 2.52) cut from the mid-section position of 25mm thick, high and low strength X166 plates to DTD 5120 and DTD 5130.

The test programme was undertaken to determine the effect of the salt-fog environment on the fatigue properties of the two alloys. At 2×10^7 cycles the fatigue strength of the high strength X166 plate (DTD 5120) was reduced by 60% (from 162 MPa to 58 MPa) while that of the low strength X166 plate (DTD 5130) was reduced by approximately 40% (from 132.5 MPa to 77.5 MPa).

Departmental Reference: Mat 362

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1 INTRODUCTION

To provide information on the fatigue properties, in laboratory air, of the new Al-Zn-Mg-Cu-Zr alloy X166, direct stress fatigue tests have been made on plain and holed test pieces cut from high and low strength plate covered by specifications DTD 5120 and DTD 5130 respectively[1]. Test pieces were taken from two plate thicknesses - 25 mm and 8 mm.

However, to assist in selecting the best aluminium alloy for a particular structural application, information was also required on the fatigue performance of the X166 alloy in a corrosive environment. The work now reported describes some direct stress fatigue tests carried out in a salt-fog environment on that alloy. The holed transverse test pieces ($K_T = 2.52$) were similar to those used for the earlier laboratory air tests[1] and were taken from the same high and low strength 25mm thick X166 plates. Direct comparisons can thus be made between the results of the tests made in laboratory air and those in a salt-fog environment.

2 MATERIAL

Alcan Booth Sheet Ltd supplied the 25mm thick plates from Melt 4 of the X166 alloy. The high strength plate (No.1) had been aged for 6 h at 169-172°C (T 7651 temper), and the low strength plate (No.2) for 10 h at 169-172°C (T 73651 temper).

Details of the plates are given in Table 1 and the chemical analysis supplied by Alcan Booth Sheet Ltd is given in Table 2.

3 TEST PIECES

No tensile test pieces were prepared from the plates for this investigation since the tensile properties had already been determined for the earlier laboratory air fatigue programme[1].

The transverse fatigue test pieces required for the corrosion fatigue tests were cut from the mid-section of the plates, as shown by Figs 1 and 2. These were RAE type 6 Vibrophore tests pieces, Fig 3, having a central reamed 2.5mm diameter hole resulting in a K_T value of 2.52. They were cut transverse to the final rolling direction of the plates by sawing, and were finally surface machined by fly cutting to give a surface finish of 0.4-0.8 μm (15-30 μin). No plain test pieces were tested.

4 TENSILE TESTS

The results of the tensile tests carried out earlier[1] are given in Tables 3 and 4. The values obtained comply with the appropriate specifications, except for the transverse 0.2% proof stress values, 472-476 MPa, for the low strength material (Table 4). These were above the permitted range of 420-465 MPa.

5 FATIGUE TESTS

5.1 Test environment

Before the test programme was commenced it was necessary to select the corrosive environment. So that the widest comparisons could be made between results obtained for X166 and those for other high strength aluminium alloys it was decided to adopt the conditions chosen by ALCOA for their corrosion fatigue tests on the 7050 plate alloy[2]. This test subjected the test section of the test piece to a 20s spray of 3½% NaCl solution at 5 min intervals.

5.2 Apparatus

All the corrosion fatigue tests were carried out in a Perspex spray box shown schematically in Fig 4. The box measured 200 mm × 100 mm × 30 mm, and had a detachable lid and a jet block let into one end. The size of the orifice in the salt solution supply tube (jet A) was 0.4 mm diameter (0.016 in) and the diameter of the air supply tube orifice B was 1.5 mm (0.060 in). Fig 5 shows in diagrammatic form the arrangement of components to spray the 3½% NaCl solution into the box. An electrical timing device was used to operate the solenoid air valve.

Specification ASTM B117 on "Salt spray fog testing" was applied to determine the environmental test conditions (fog density) in the box. The specification recommends an hourly deposit of liquid of 1-2 ml over a catchment area of 80 mm^2, without drips from the box lid. Our trials indicated that these conditions could be met by a head of liquid of minus 20 mm and an air pressure of 10 psi for spraying purposes, operating intermittently for 20 s every 5 min.

The test piece was sealed into the spray box at top and bottom using a silicone rubber compound. The bottom was first sealed and allowed to cure for 3 h. The top was then sealed and the whole assembly was cured for a further 4 h before being assembled into the wedge grips of the testing machine. Thus the bottom seal had a curing time of 7 h before liquid was introduced into the spray box.

The pH value of the 3½% NaCl solution was between 6.5 and 7.2. Liquid which had collected on the bottom of the box was led to waste, and the fog was also vented to waste via a tube remote from the jet block.

5.3 Fatigue tests

All the fatigue tests were carried out in fluctuating tension, $R = 0.1$, in a 10tonf Vibrophore fatigue testing machine operating at a frequency of approximately 130 Hz. The results of these tests are given in Tables 6 and 8. Comparative tests which were made in laboratory air (RH $\sim$ 40%) and reported earlier[1] are given in Tables 5 and 7. The S-N curves for the test pieces from the high strength plate (DTD 5120) are given in Fig 6 and those from the low strength plate (DTD 5130) in Fig 7. A summary of the fatigue test results is given in Table 9.

6 DISCUSSION OF FATIGUE RESULTS

The effect of the 3½% NaCl fog environment on the holed fatigue performance of X166 in both strength conditions can be seen in Figs 6 and 7. There was far more scatter in the results of the corrosion fatigue tests when compared to the tests made in laboratory air. None of the test pieces survived unbroken for 10^8 cycles in the tests made in salt fog. Comparisons with performance in laboratory air can therefore only be made at lives up to 8×10^7 cycles for the high strength plate and up to 3×10^7 cycles for the low strength plate.

Fig 6 also shows in dotted lines, two fatigue curves taken from Fig 141 of an ALCOA report[2]. The sheet alloy concerned, 7050-T76, is very similar in composition to X166, except for a slightly higher copper content (2.25%). The ALCOA transverse direction fatigue test pieces had an edge notch ($K_T = 3$) and were subjected to fluctuating tension ($R = 0$). Since there are a number of differences between the ALCOA tests and the present tests in both test pieces and testing procedure no direct comparisons of the relative effect of the salt fog upon the fatigue properties of the two alloys is possible, although a marked difference between the properties in laboratory air and salt fog is also evident for the 7050-T76 plate. The ALCOA tests show a drop in fatigue strength of approximately 30% at 10^6 cycles for the 7075-T76 plate compared with a reduction of approximately 40% for the higher strength X166 (DTD 5120) at the same endurance.

7 FURTHER WORK

Similar work is in hand to compare the corrosion fatigue strengths of the
114 aluminium-copper-magnesium alloys BSS L93 and BSS L97 with their fatigue

strengths in laboratory air. Tests will be made (a) in a 3½% NaCl fog environment and (b) completely immersed in a 3½% NaCl solution.

8 CONCLUSIONS

(1) When tested in a 3½% NaCl fog, the fatigue strength at 2×10^7 cycles of holed (K_T = 2.52) transverse test pieces cut from the mid-section of 25mm thick high strength X166 plate (DTD 5120) showed a reduction of about 60% in peak stress when compared with laboratory air tests. This reduction was from 162 MPa to 58 MPa.

(2) Under the same conditions of test, holed (K_T = 2.52) transverse fatigue test pieces from the mid-section of 25μm thick low strength X166 plate (DTD 5130) showed a reduction of about 40% in peak stress when compared with laboratory air tests.

The reduction was from 132.5 MPa to 77.5 MPa.

(3) Therefore, although in laboratory air the fatigue strength at 2×10^7 cycles of the high strength X166 plate (DTD 5120) was about 20% greater than the low strength X166 plate (DTD 5130), the latter plate was about 30% stronger than the high strength plate (DTD 5120) when tested in the 3½% NaCl fog.

Table 1

DETAILS OF X166 PLATES USED FOR FATIGUE TESTS

Plate No. for test programme	Plate designation	Plate thickness mm	Temper	Cast No.	Alcan test report No.
1 (DTD 5120)	P68260 (TX060B)	25	T7651	2C229/7	727JG4
2 (DTD 5130)	P68260 (TX078)	25	T73651	2C229/7	733JG4

Table 2

CHEMICAL COMPOSITION OF PLATES 1 AND 2

Plate thickness and test report Nos.		Weight %								
		Zn	Mg	Cu	Zr	Fe	Si	Mn	Ti	Cr
	DTD 5120/5130 Specification Range	6.7 5.7	2.7 2.2	2.0 1.5	0.17 0.11	0.15 max	0.10 max	0.30 max	0.05 max	0.05 max
25 mm 727 JG4 733 JG4	Actual Composition	6.01	2.33	1.74	0.11	0.10	0.08	0.02	0.02	<0.01

Table 3

RESULTS OF TENSILE TESTS IN LABORATORY AIR ON TEST PIECES FROM THE MID-SECTION OF 25mm HIGH STRENGTH X166 PLATE (DTD 5120) (Ref 1)

Direction	Transverse		Longitudinal	
Test piece No.	IT1	IT2	IT3	IT4
0.1% PS MPa	488	488	506	505
0.2% PS MPa	500	502	517	514
0.5% PS MPa	508	516	523	522
TS MPa	554	554	564	562
'E' GPa	73	72	72	72
Elong % on 50 mm	12	12	12	13

Table 4

RESULTS OF TENSILE TESTS IN LABORATORY AIR ON TEST PIECES FROM THE MID-SECTION OF 25mm LOW STRENGTH X166 PLATE (DTD 5130) (Ref 1)

Direction	Transverse		Longitudinal	
Test piece No.	2T1	2T2	2T3	2T4
0.1% PS MPa	457	455	459	460
0.2% PS MPa	476	472	469	471
0.5% PS MPa	486	482	477	479
TS MPa	534	534	527	530
'E' GPa	72	72	73	73
Elong % on 50 mm	13	12	11	13

Table 5

RESULTS OF FATIGUE TESTS IN LABORATORY AIR ON HOLED (K_T = 2.52) TRANSVERSE TEST PIECES FROM THE MID-SECTION OF 25mm THICK HIGH STRENGTH X166 PLATE (DTD 5120) (Ref 1)

R = 0.1

Test piece No.	Peak applied stress		Endurance 10^6 cycles	Remarks
	MPa	tonf/in^2		
1N6	232	15.0	0.034	B
1N10	216	14.0	0.048	B
1N4	201	13.0	0.056	B
1N8	185	12.0	0.211	B
1N9	171	11.1	0.232	B
1N2	167	10.8	4.484	B
1N5	161	10.4	100.000	UB
1N12	154	10.0	100.000	UB
1N3	105	6.8	100.000	UB

B = broken test piece. UB = unbroken test piece.

Table 6

RESULTS OF FATIGUE TESTS IN 3½% SALT FOG ON HOLED (K_T = 2.52) TRANSVERSE TEST PIECES FROM THE MID-SECTION OF 25mm HIGH STRENGTH X166 PLATE (DTD 5120)

R = 0.1

Test piece No.	Peak applied stress		Endurance 10^6 cycles	Remarks
	MPa	tonf/in^2		
1N19	185	12	. 0.012	B
1N14	154	10	0.093	B
1N18	143	9.3	0.675	B
1N13	123	8.0	2.261	B
1N22	108	7.0	0.412	B
1N15	92.4	6.0	14.994	B
1N16	77	5.0	19.239	B
1N17	61.6	4.0	41.248	B
1N20	54	3.5	16.545	B
1N21	38.5	2.5	61.578	B

Table 7

RESULTS OF FATIGUE TESTS IN LABORATORY AIR ON HOLED (K_T = 2.52) TRANSVERSE TEST PIECES FROM THE MID-SECTION OF 25mm THICK LOW STRENGTH X166 PLATE (DTD 5130) (Ref 1)

R = 0.1

Test piece No.	Peak applied stress		Endurance 10^6 cycles	Remarks
	MPa	tonf/in^2		
2N9	247	16.0	0.036	B
2N7	216	14.0	0.051	B
2N11	185	12.0	0.161	B
2N5	154	10.0	0.285	B
2N4	139	9.0	1.137	B
2N2	131	8.5	100.000	UB
2N6	123	8.0	100.000	UB

Table 8

RESULTS OF FATIGUE TESTS IN 3½% SALT FOG ON HOLED (K_T = 2.52) TRANSVERSE TEST PIECES FROM THE MID-SECTION OF 25mm THICK LOW STRENGTH X166 PLATE (DTD 5130)

R = 0.1

Test piece No.	Peak applied stress		Endurance 10^6 cycles	Remarks
	MPa	tonf/in^2		
2N20	232	15.0	0.028	B
2N16	185	12.0	0.143	B
2N15	154	10.0	2.080	B
2N17	139	9.0	0.783	B
2N14	123	8.0	4.606	B
2N21	108	7.0	6.864	B
2N18	92.4	6.0	26.299	B
2N13	77	5.0	4.123	B
2N22	69	4.5	8.219	B
2N19	61.6	4.0	24.937	B

Table 9

SUMMARY OF FATIGUE TESTS

Material 25mm thick X166 plate	Fatigue strength (MPa) at 2×10^7 cycles		Reduction in fatigue strength %
	Air	Salt fog	
High strength (DTD 5120)	162	58	64
Low strength (DTD 5130)	137.5	77.5	42

REFERENCES

No.	Author	Title, etc
1	J.T. Ballett N.J.F. Gunn P.J.E. Forsyth	The axial loading fatigue properties of 25 and 80mm thick high and low strength X166 plate (DTD 5120). RAE Technical Report 77123 (1977)
2	R.E. Davies G.E. Nordmark J.D. Walsh	Design mechanical properties, fracture toughness, fatigue properties, exfoliation and stress corrosion properties of 7050 sheet, plate, hand forgings, die forgings and extrusions. ALCOA NASA Contract No. N00019-72-C-0512, 12 May to 12 November 1974
3	-	Salt spray fog testing. ASTM Specification B117

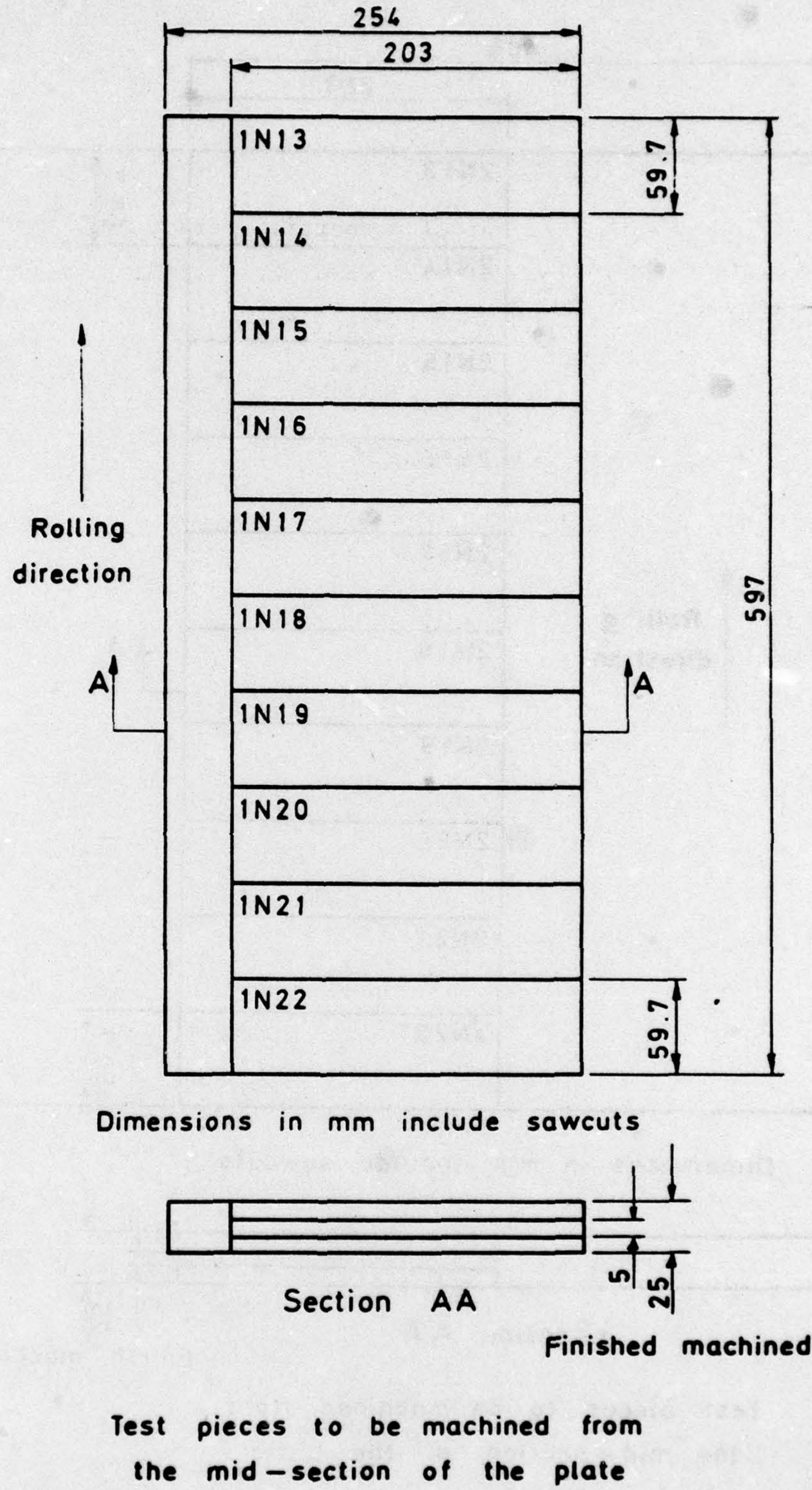

Fig 1 Cutting diagram of test pieces from 25mm high strength plate

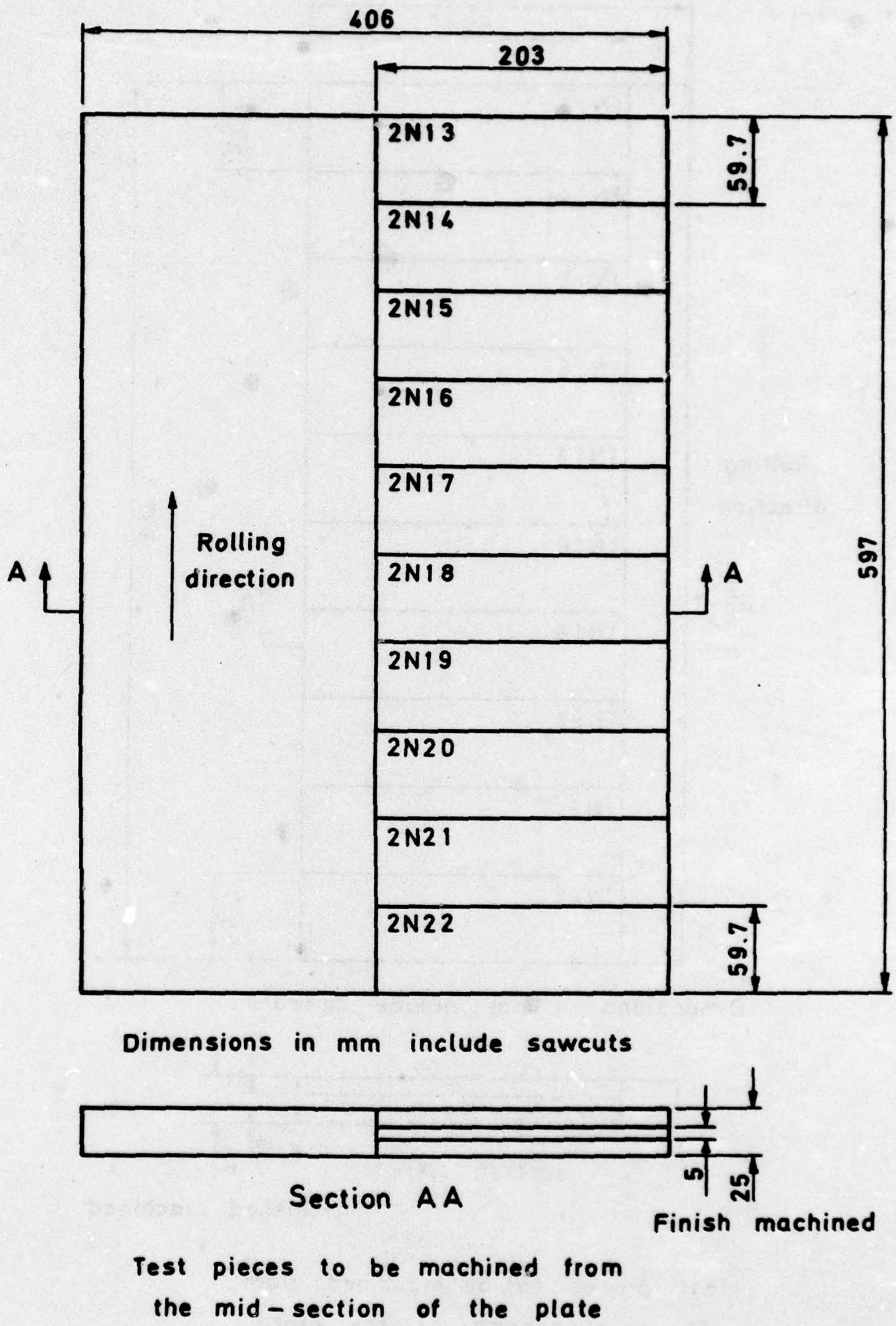

Fig 2 Cutting diagram of test pieces from 25mm low strength plate

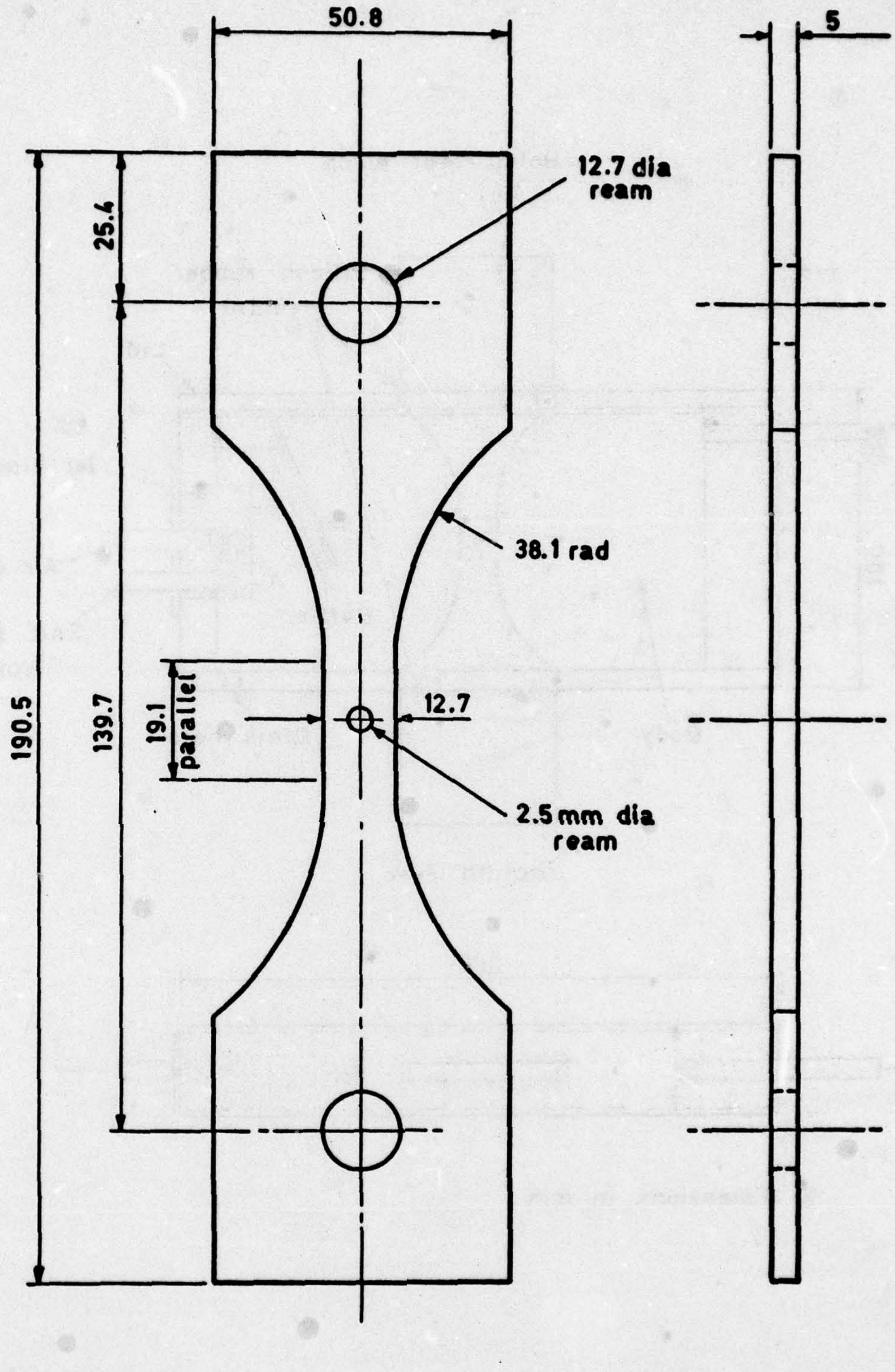

Fig 3 Vibrophore holed test piece, $K_T = 2.52$, type 6

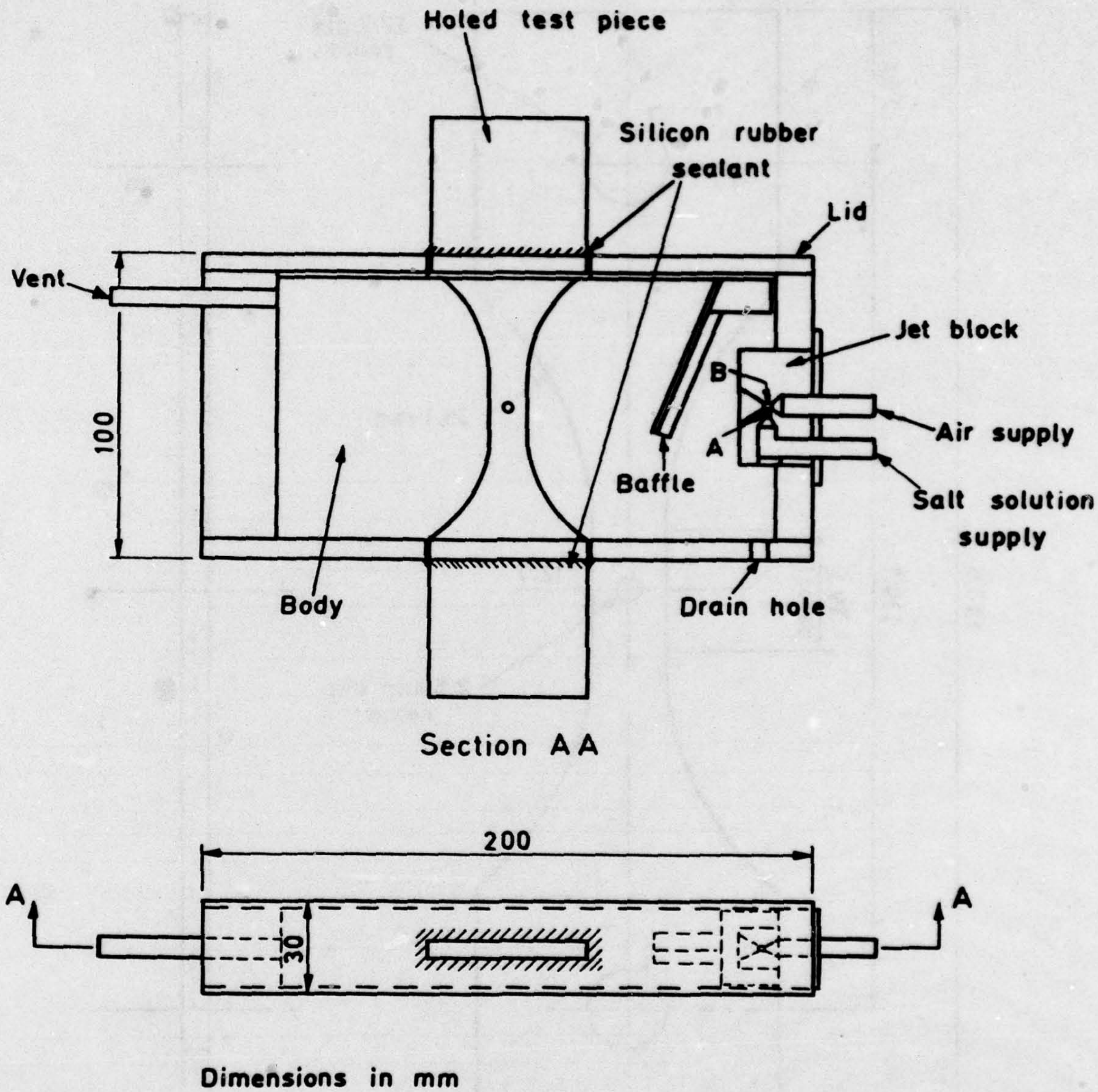

Fig 4 Perspex spray box

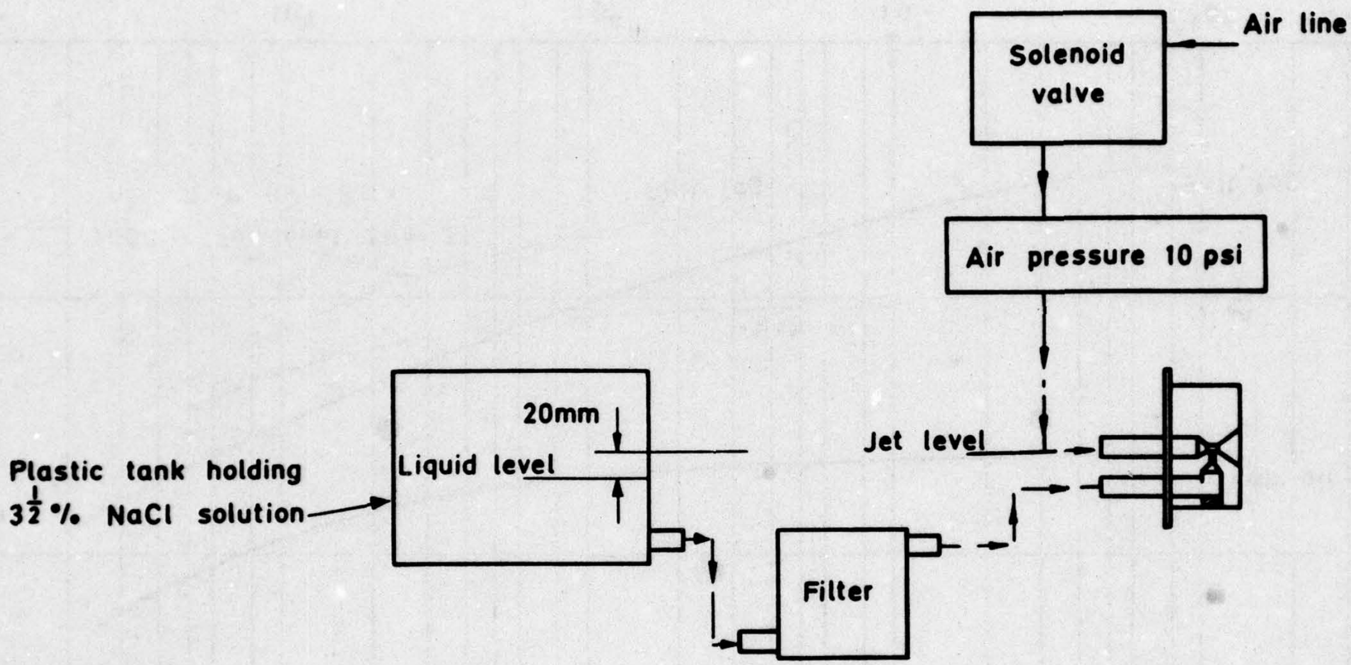

Fig 5 Block diagram showing arrangement spray components

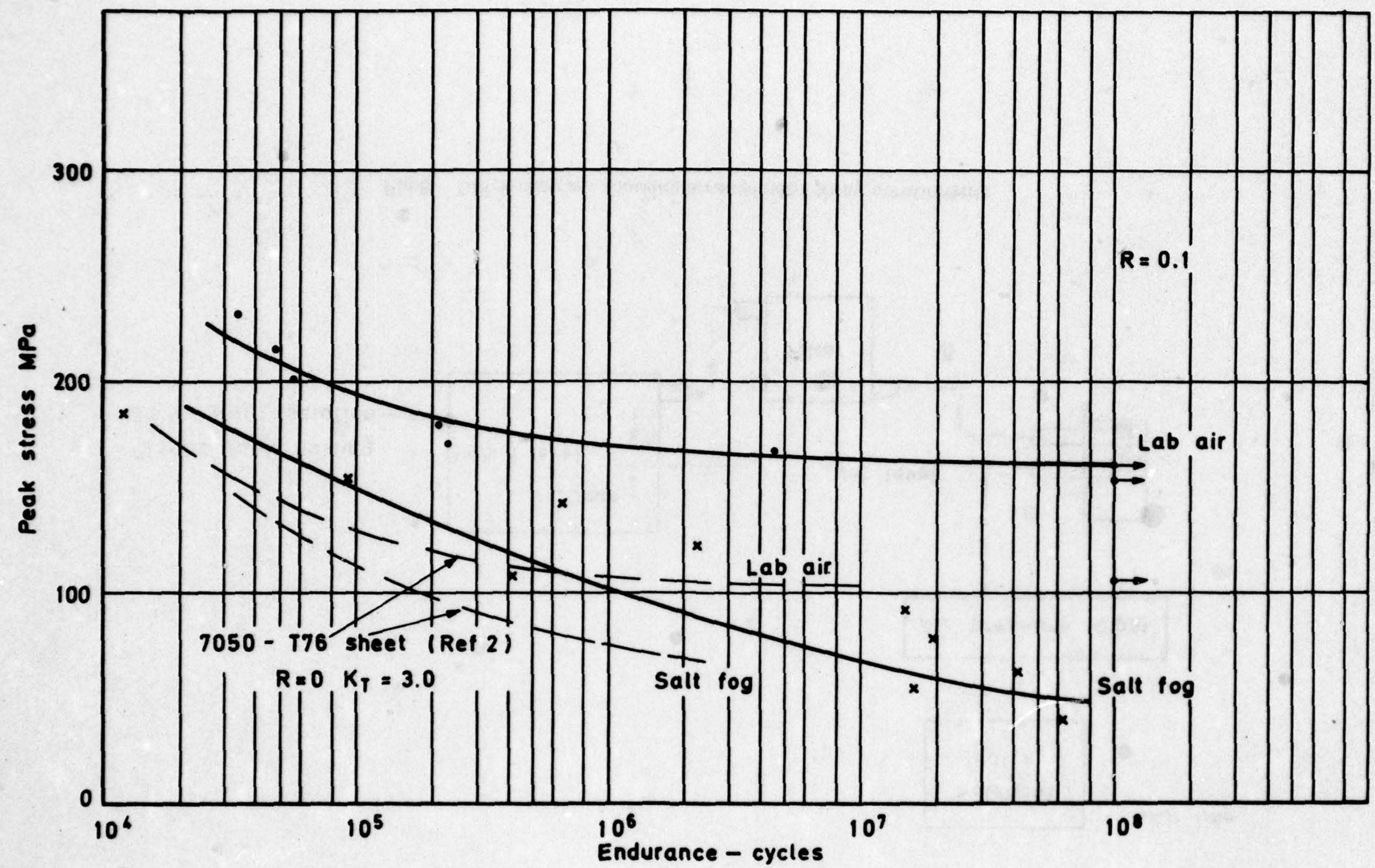

Fig 6 Fatigue tests on holed ($K_T = 2.52$) transverse test pieces from 25mm high strength X166 plate (DTD 5120)

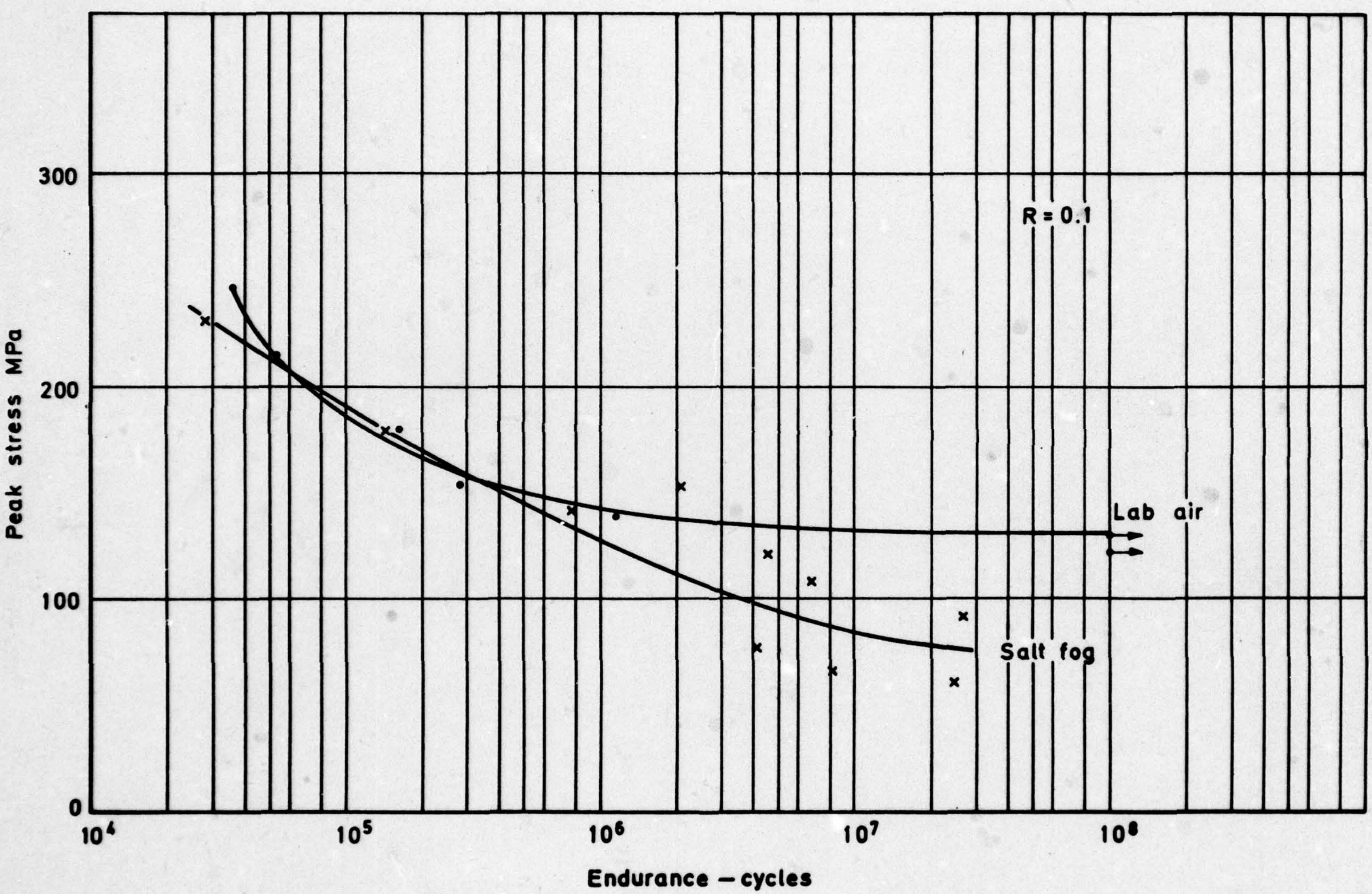

Fig 7 Fatigue tests on holed (K_T = 2.52) transverse test pieces from 25mm low strength X166 plate (DTD 5130)

REPORT DOCUMENTATION PAGE

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17\. Abstract

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The test programme was undertaken to determine the effect of the salt-fog environment on the fatigue properties of the two alloys. At 2×10^7 cycles the fatigue strength of the high strength X166 plate (DTD 5120) was reduced by 60% (from 162 MPa to 58 MPa) while that of the low strength X166 plate (DTD 5130) was reduced by approximately 40% (from 132.5 MPa to 77.5 MPa).

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